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MENSURATION AND CAPACITY OF THE FEMALE BLADDER

OBSERVATIONS ON THE FEMALE BLADDER DILATED BY ATMOSPHERIC PRESSURE IN THE KNEE-BREAST POSTURE

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The investigations here reported were undertaken by the writers on the suggestion and with the constant aid and direction of Dr. Howard A. Kelly, of the Johns Hopkins Hospital, to whom they take pleasure in acknowledging their indebtedness.

The interest attaching to the work, of course, is quite limited, as the subject is technical and at present internal examinations of the bladder for the purpose of diagnosis and treatment is employed by relatively few physicians and surgeons. However, such examination is yearly becoming more general and its usefulness is becoming better recognized, and hence any additional information on the size and topography of the bladder is not without value.

How little is really known about the bladder is found on a cursory reading of the surgical text-books, containing their meager and contradictory statements. The measurements and capacity of the female bladder given in the text-books have been determined by post-mortem examination, by urine—or other fluid—distension to discomfort, and by other inexact methods that have given imperfect and often contradictory results.

The methods employed by the writers in their investigation differ from those heretofore employed in essential respects. 1. All measurements were made on living women with the bladder either perfectly healthy —most cases—or so slightly disturbed from the normal as not to affect the accuracy of the results. 2. All examinations were made with the women in the knee-breast posture, with the rectum, vagina, and bladder all—with a few exceptions noted in the accompanying table—dilated by atmospheric pressure, produced by simply opening these cavities to the outside air by the insertion of a speculum, by the method so well known from the writings of Kelly.

With all cases thus placed under similar conditions of observation, the chief sources of avoidable error were removed, and relative measurements could be made and certain averages and standards found. It was, of course,

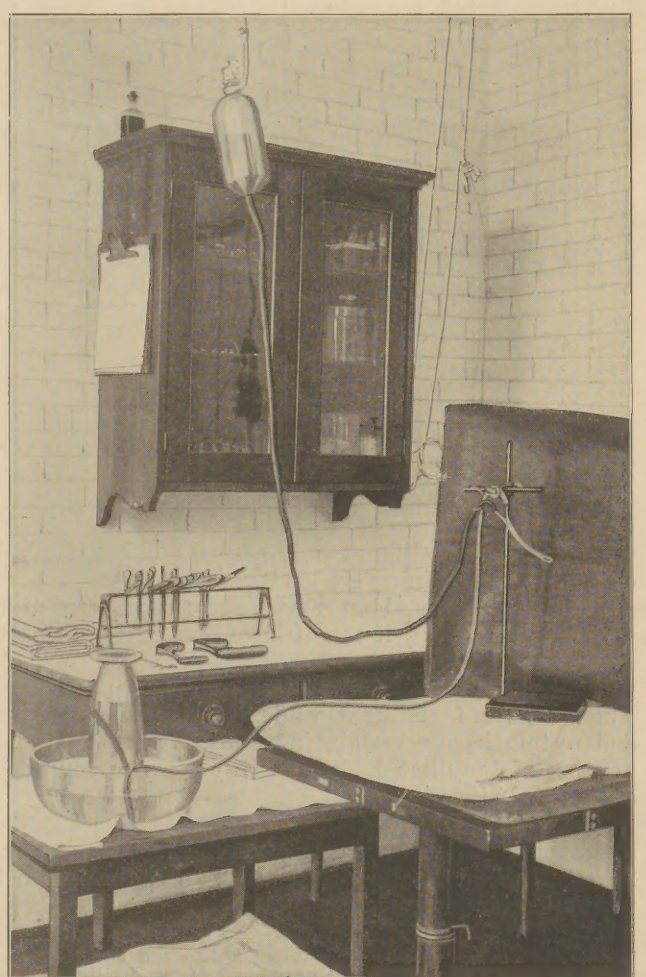

Fig. 1 represents the double-barreled catheter and attachment, and for determining the residual air in the bladder after bimanual expansion.

impracticable to estimate the variations of intra-abdominal pressure in different cases or to fix upon a standard of this force, but repeated examinations of the capacity of the bladder in the came case showed that this force was nearly uniform. Although this force may be assumed to vary in different cases and thus to influence the capacity of the bladder when it is opened to the entrance of the outside air, still we believe that this variation is far less important than the variation of individual tolerance or irritability to fluid distension, the method previously most generally employed in determining the capacity of the bladder.

It was found also that by this method of dilatation no discomfort[1] was felt by the woman, and consequently no resistance, either voluntary or involuntary, was offered by her, thus adding to the uniformity of the conditions of observation. On the contrary, it was found that distension by fluid to discomfort was subject to the peculiar and varying irritability or tolerance of the subject, and thus gave no uniform basis of comparison.

The work was undertaken primarily to afford to the gynecologist some additional information on the size, shape, position, internal mensuration, and capacity of the bladder when dilated with air with the patient in the knee-breast position, i. e., the usual and best method employed in examining the bladder internally.

Had the study been made primarily from the anatomic viewpoint, it might have been better to have made the observations on the bladder alone distended, without the distension also of the vagina and rectum. But we have found that while the distended vagina and rectum have a certain influence on the shape and position of the dilated bladder, they seem to influence only slightly its air capacity.[2]

The chief points investigated were: 1, the average atmospheric distension capacity of the female bladder, 2, its actual internal measurements from the internal urethral orifice to certain chosen points on its walls.

For the purpose of the first study, the woman was put in the knee-breast posture and the three pelvic cavities were each allowed to dilate with air. A closely fitting catheter was then introduced into the bladder, attached at its external end to a long soft rubber tube. The rubber tube was closed by clamp, and the woman was then rotated carefully by assistants from the knee-breast into the dorsal position. The rubber tube was then introduced into a deep vessel of water and from below upward into an inverted glass, graduated cylinder completely filled with water, and was held pointing upward in this position, by an assistant. The clamp on the tube was then released, and the entire air content of the bladder was expressed by the ordinary gynecologic bimanual method, with one hand exerting pressure on the bladder externally from the abdominal wall and the other pressing at the same time on the bladder from within the vagina or rectum.

The air thus expressed was gathered in the glass cylinder, displacing from above downward an equal amount of water, and the amount was read off on the graduated cylinder, thus determining the exact air capacity of the bladder.

To test whether all the air was thus removed from the bladder a special instrument was devised (Figs. 1 and 2), consisting of a metal catheter, divided by a horizontal septum through its entire length, each compartment of the catheter opening separately at the bladder end of the instrument, and also at the external, here being drawn out into separate round tubes for attachment to rubber tubes. The opening of the upper chamber at the bladder end of the instrument was guarded by a wire cage covering it, and thus protected against injury to the mucous membrane of the bladder by suction, at the same time preventing an entire closure of the exit by the collapsing mucous membrane.

After the patient has been rotated from the knee-breast into the dorsal position, this double catheter, its lower chamber having been previously shut off by clamp, is inserted and through its upper chamber the air content of the bladder is collected in the way already described, by bimanual pressure on the bladder.

The rubber tube connecting with the upper chamber

Case.	Age.	Size.	Para.	Bladder.	Pelvic organs.	Anesthesia.	Time in position.	Air in		Urethra.			Mensuration of bladder.				Bladder capacity.	
								Rectum.	Vagina.	Caliber. mm.	Length. cm.	Intern. orifice closes.	Int. orifice of urethra to				Air. c.c.	Fluid. c.c.
													Vertex. cm.	Pos. wall. cm.	Left lat. wall. cm.	Right lat. wall. cm.		
1	19	Large.	O	Normal.	Left cystic ovary.	O	15 m.	+	+	8	3.75	. . . . .	7.00	5.75	7.00	6.00	350	440
2	27	Small.	O	Normal.	Small right ovarian cyst.	Ether.	30 m.	+	+	7	3.50	Hexagonal.	7.00	7.50	6.50	6.50	300	520
3	51	Large.	iii	Normal.	Normal.	Ether.	15 m.	?	?	8	3.30	Quadrangular.	5 00	7.00	5.20	4.80	225	380
4	20	Large.	O	Normal.	Small uterus.	Ether.	30 m.	+	+	8	3.00	. . . . .	7.00	6.50	6.75	6.75	235	
5	53	Large.	ii	Trigonitis.	Normal.	Ether.	15 m.	?	?	7	3.50	Narrow slit.	7.30	5.80	6.00	5.30	380	400
6	36	Small.	iv	Normal.	Relaxed vag. outlet.	Ether.	15 m.	+	+	8	3.20	. . . . .	2.20	2.20	2.80	0.80	230	500
7	29	Large.	O	Normal.	Retroflexio ut. Left salpingitis.	Ether.	15 m.	+	+	. .	4 00	Pentangular.	4.80	1.80	3.80	2.80	160	210
8	18	Medium.	O	Normal.	Normal.	Ether.	15 m.	+	+	7	2.80	. . . . .	10.30	7.80	8.80	6.30	400	400
9	19	Large.	ii	Normal.	Slight double salpingitis.	Ether.	?	?	?	6	3.50	Transversely ellipsoidal.	8 00	6.80	8.00	6.80	275	425
10	17	Large.	O	Normal.	Anteflexio uteri.	O	15 m.	+	+	7	3 00	Triangular.	7.50	6.00	6.80	5.50	220	460
11	48	Large.	Para.	Normal.	Normal.	Ether.	15 m.	?	?	. .	3.00	Pentagonal.	8.30	6.80	7.30	6.00	210	440
12	35	Medium.	O	Normal.	Normal.	Ether.	15 m.	+	+	7	3.50	Circular.	6.80	5.30	6.80	4.80	275	360
13	39	Large.	O	Normal.	Left ovarian adhesion to broad ligament.	Ether.	15 m.	+	+	7	3.50	Pentagonal.	9.20	6.20	8.20	8.70	545	840
14	34	Medium.	Para.	Normal.	Normal.	Ether.	15 m.	+	+	. .	. . .	Quadrangular.	7.70	5.70	6.70	5.70	290	400
15	27	Very large.	O	Normal.	Normal.	Ether.	30 m.	+	+	. .	2.75	Triangular.	8.20	6.70	7.20	7.20	400	500
16	19	Small.	O	Normal.	Normal.	Ether.	30 m.	+	+	6.5	3.00	Pentagonal.	8.20	6.20	8.20	6.20	350	600
17	28	Small.	vi	Normal.	Prolapsus uteri.	O	15 m.	+	+	6	4.20	Hexagonal.	7.20	6.20	7 20	7.70	220	300
18	39	Medium.	Para.	Normal.	Suspensio uteri. Salpingitis, oöp.	O	15 m.	+	+	6	3.00	. . . . .	6.20	6.20	6.70	6.20	300	220
19	24	Small.	O	Mild cystitis.	Normal.	O	15 m.	O	+	. .	. . .	. . . . .	5.70	5.20	5.90	5.20	240	
20	23	Large.	i	Normal.	Normal.	Ether.	15 m.	?	?	8	. . .	Pentagonal.	8.00	7.20	6.70	6.70	520	450
21	52	Large.	vi	Trigonitis.	Normal.	O	15 m.	+	+	. .	. . .	Tranverse slit.	7.70	6.20	8.20	7.20	320	480
22	24	Small.	Para.	Normal.	Normal.	Ether.	30 m.	+	+	. .	. . .	. . . . .	5.20	3.20	4.20	4.20	200	
23	19	Medium.	O	Mild cystitis.	Normal.	O	15 m.	+	+	. .	. . .	. . . . .	7.20	5.40	7.20	7.40	385	460
24	26	Small.	Para.	Acute cystitis.	Retropos. uteri.	O	30 m.	+	+	8	. . .	. . . . .	9.20	6 20	7 20	7.20	325	350
25	52	Large.	O	Mild cystitis.	Normal.	Ether.	30 m.	+	+	. .	. . .	Circular.	7.70	4.40	8.20	6.20	220	320

[1] The patients never complained of discomfort from the distended bladder while in the knee-breast posture. After rotation to the dorsal position, however, they usually felt some slight discomfort, if they were not under anesthesia, and were instructed, before being rotated, to refrain from any expulsive effort.

[2] This last statement needs confirmation, as our observations on this point were few.

is then shut off by clamp, and a sterile boric solution, colored slightly with methylene blue, is passed into the bladder through the lower chamber of the catheter by hydrostatic pressure from outside, the tube connecting with a glass vessel filled with the fluid and raised above the level of the bladder to produce the required hydrostatic pressure to fill it. The catheter, which is curved, is depressed externally so that its end within the bladder is raised to the anterior—upper—wall of the bladder and is felt against the abdominal wall by the hand placed against it externally.

In the twenty-five women examined, the average bladder capacity by atmospheric distension was found to be 303 c.c., individual cases ranging from a minimum of 160 to a maximum of 545 c.c. By reference to the accompanying table it will be seen that the capacity in general follows the general size of the bladder by internal mensuration, and also in a general way the size of the woman. Measurement was also made, in 22 cases, of the fluid content of the bladder, boric solution being used for this purpose. On anesthetized patients the solution was introduced through the double-barreled cathe-

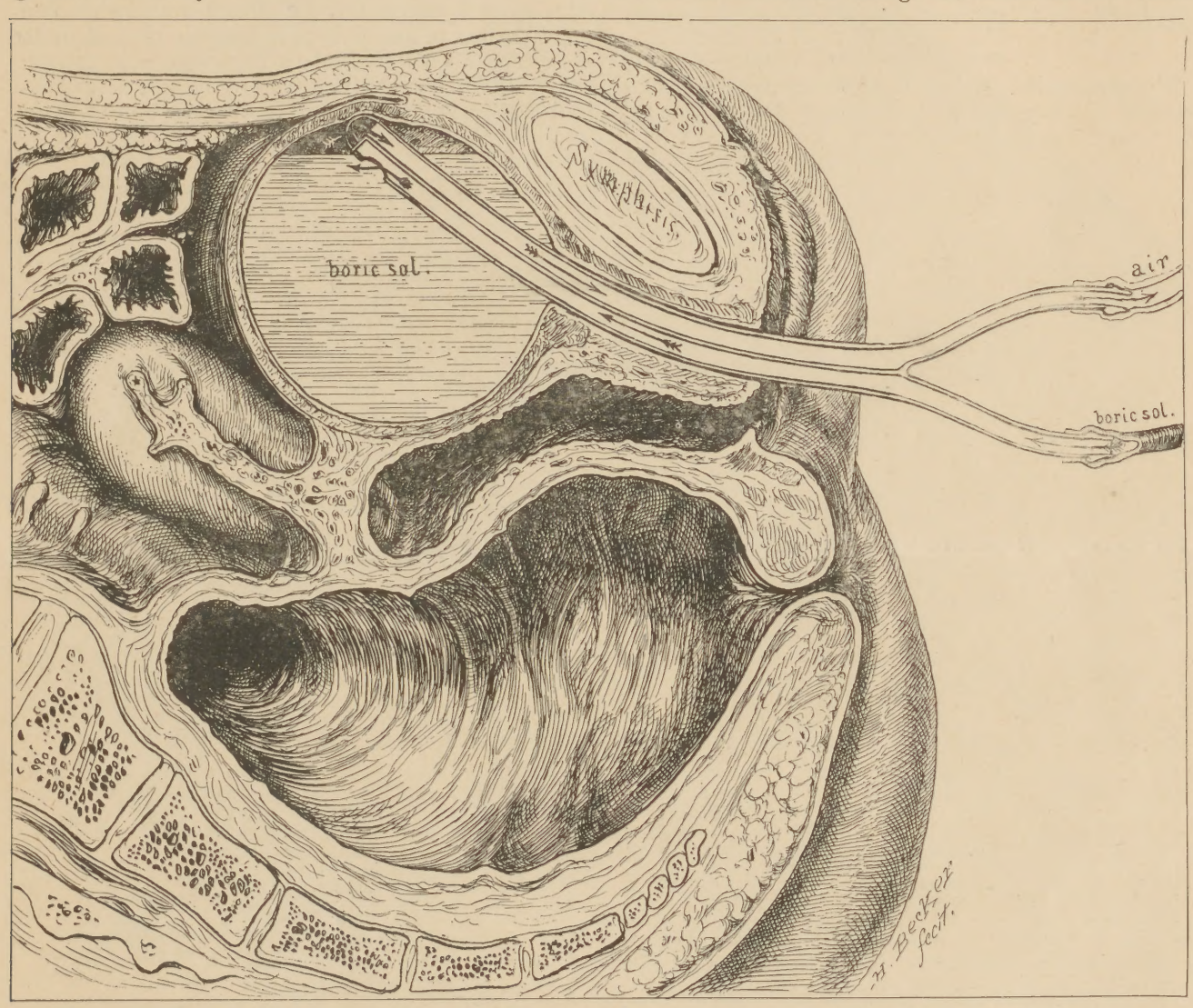

FIG. 2.—Median section, dorsal position, showing the double-barreled catheter in position in the bladder, boric solution entering through the lower chamber and forcing the air out through the upper chamber.

When the bladder is filled to moderate distension by fluid, and air remaining in it would naturally rise to the highest level and thus find its way out through the upper passage of the catheter, then the clamp on the rubber tube connected with it externally is released. This air is forced out by the pressure of the fluid within the bladder seeking to escape, and is then collected and measured.

The amount of air thus obtained ranged from 5 to 30 c.c., averaging about 15 c.c., which was found by measurement to correspond to the air content of the catheter and attached tube. It was thus shown that the total air content of the bladder had in general been completely removed by the previous bimanual expression.

ter until overflow through the upper barrel; on those without anesthesia, until discomfort was caused to the woman. The average fluid capacity was thus found to be 429.7 c.c., varying in individual cases from a minimum of 210 to a maximum of 840 c.c. The fluid capacity of the bladder was thus found to be more than one-third greater than the air capacity, a difference that would be expected because of the elasticity of the bladder walls under increased pressure.

With reference to the influence of anesthesia on the capacity, the following table has been arranged:

	Atmospheric capacity.	Fluid capacity.
With anesthesia . . .	306.7 c.c. (av. 17 cases)	449.6 c.c. (av. 15 cases)
Without anesthesia .	295.0 c.c. (av. 8 cases)	387.1 c.c. (av. 7 cases)
	303.0 c.c. (av. 25 cases)	429.7 c.c. (av. 22 cases)

From these figures it is seen that the average capacity of the bladder for both air and fluid is somewhat greater with than without anesthesia, explained, doubtless, by the relaxation of the bladder walls during anesthesia. The above figures tend also to show that this difference is greater with fluid than with atmospheric distension, due to the greater irritability of the bladder, without anesthesia, to fluid distension.

The influence of child-bearing on the capacity of the bladder is shown in the following table:

	Atmospheric capacity.	Fluid capacity.
Nulliparous.	313.8 c.c. (av. 13 cases)	464.5 c.c. (av. 11 cases)
Parous	291.2 c.c. (av. 12 cases)	395.0 c.c. (av. 11 cases)
	303.0 c.c. (av. 25 cases)	429.7 c.c. (av. 22 cases)

The explanation of these figures, showing the greater capacity of the bladder of nulliparæ, is doubtful, and it may be that it is purely accidental, due to the limited number of cases observed. We would suggest, however, that it may be due to the greater elasticity of the bladder of the nullipara, influenced both by her younger average age, and by the fact that her bladder and the surrounding tissues have not suffered injury and undergone sclerotic changes as the result of the pressure of the gravid uterus. The influence of age is shown in the fact that the average age of the women who had borne children was 36, and of the nulliparous women only 26 years.

The second chief object of this study was to gather some statistics on the internal mensuration of the bladder under atmospheric dilatation in the knee-breast posture. The value of such measurements to the gynecologist is apparent, but they have never before been accurately ascertained.

The distance of certain points from the internal urethral orifice was measured. The points chosen were: 1. The *vertex,* or summit, the most prominent and distant point in the concavity of the upward and anterior bulging of the ventral wall, usually placed well above the reflexion of the peritoneum and the departure of the urachus. 2. The most prominent and distant point in the upward and dorsal bulging of the *posterior wall.* This point is found a few centimeters above the peritoneal reflexion, and is usually opposite the end of the cystoscope when it is held in the axis of the patient's body. Quite frequently, however, the cystoscope must be directed more posteriorly to bring this point into view.

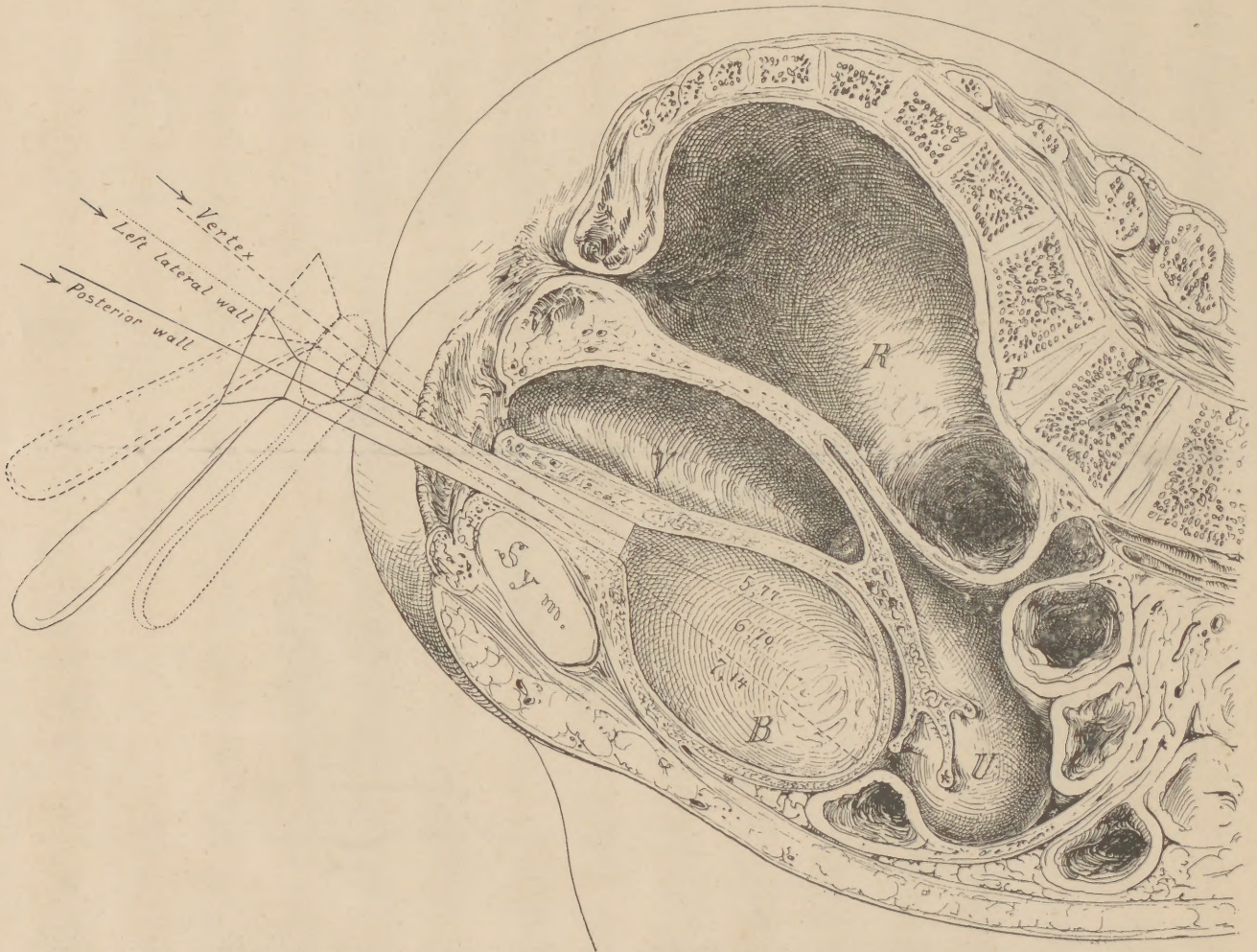

Fig. 3.—Median section, knee-breast posture, showing the pelvic cavities dilated by atmospheric pressure, and the cystoscope in position for obtaining the measurements of the vertex, posterior wall, and left lateral wall.

3. The point of greatest outward bulging in the *left lateral wall.* 4. The point of greatest outward bulging in the *right lateral wall.* These four points are not scientifically fixed points, but in actual work are found to be sufficiently clearly indicated for practical purposes of identification and description (Fig. 3).

The average measurements obtained for these four points were: to summit, 7.14 cm.; to posterior wall, 5.77 cm.; to left lateral wall, 6.70 cm.; to right lateral wall, 5.92 cm. The individual measurements will be found in the accompanying table.

Taking the measurements separately for nulliparous and for parous women, the averages are found to be as follows:

	Summit.	Posterior wall.	Left lateral wall.	Right lateral wall.
Nulliparous (av. 13 cases)..	7.43 cm.	5.75 cm.	7.03 cm.	6.12 cm.
Parous (av. 12 cases) . . .	6.83 cm.	5 79 cm.	6.35 cm.	5.72 cm.

The greater average internal dimensions of the bladder of nulliparæ, here shown, correspond to the greater capacity for air and fluid, as already pointed out, and may be explained in the same way.

noticed by anatomists, but never before has this asymmetry been recorded in so large a proportion of cases. This tendency for the bladder to be placed more to the left than to the right, at least when the patient is in the knee-breast posture with the three pelvic cavities dilated with air, may be explained by the fact that the rectum in women is found much more commonly on the

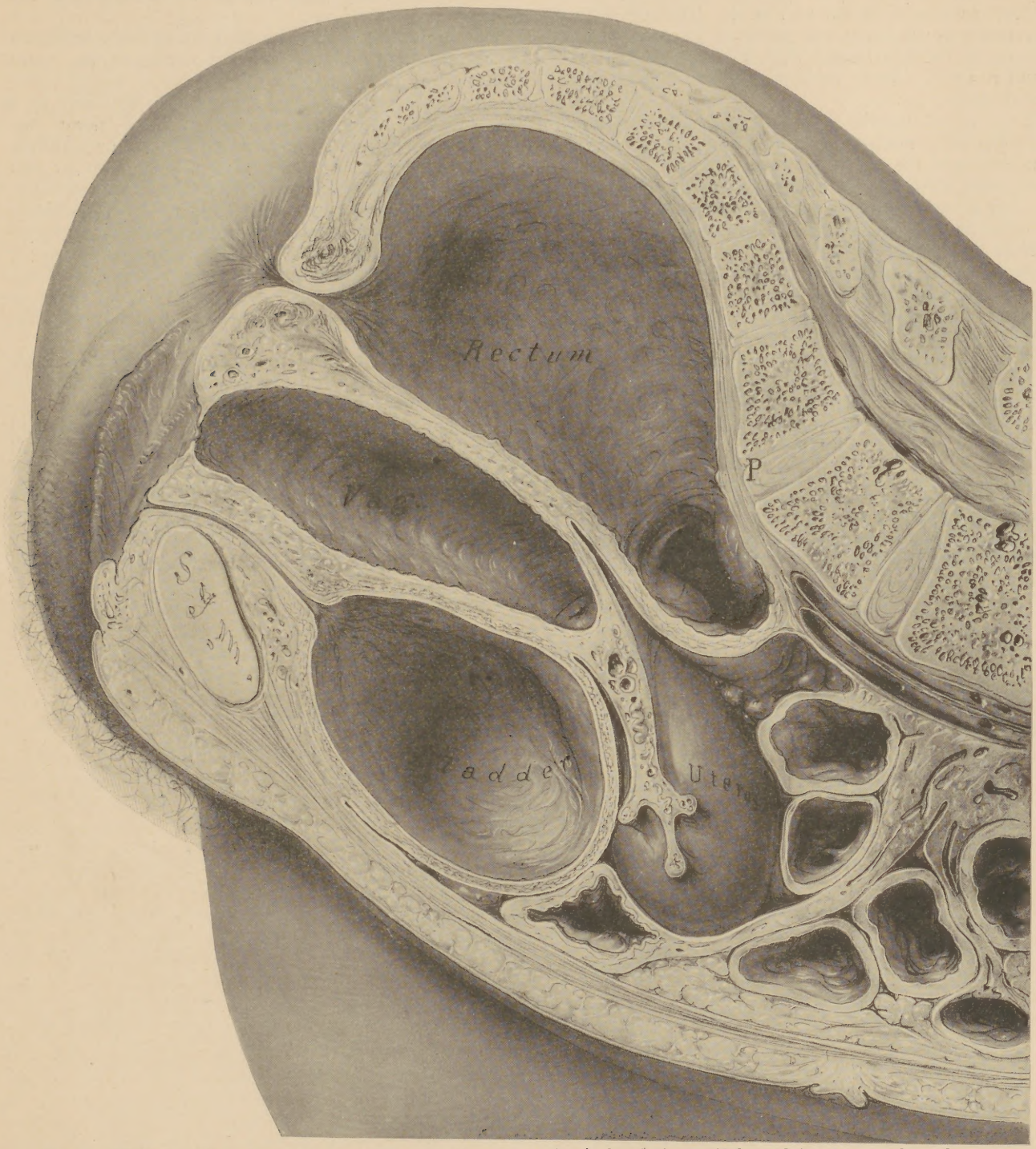

FIG. 4.—Median section, knee-breast posture, showing the anatomical relations of the pelvic organs when the rectum, vagina, and bladder are dilated by atmospheric pressure.

The *asymmetry* of the dilated bladder, shown by the unequal lateral measurements, is of interest. In sixteen cases the left lateral measurement is greater than the right; the reverse is true in six, and in three the left and right internal lateral measurements are equal. The occasional asymmetric position of the bladder has been

right than on the left within the pelvis, and thus the distended rectum tends to displace the bladder toward the left. Our observations on the position of the rectum in women are directly opposed to the usual statements of the text-books of anatomy and surgery. Mr. Max Brödel, artist to the gynecologic department of the

Johns Hopkins Hospital[3], whose observations on the anatomy of the organs of the pelvic cavity have been exact and extensive, informs us that his own experience confirms our observations on this point.

Another factor producing some slight asymmetry of the dilated bladder is the fact that the uterus[4] is usually placed somewhat to the left of the median line and encroaches on the left upper posterior quadrant of the bladder, as is well shown in Fig. 4. The influence of this factor is to lower the point of greatest outward bulging of the left lateral wall, Point 3, so that it is found to be at a lower level than Point 4 on the right lateral wall.

It was found that the same patient examined repeatedly by the same method gave, as a rule, nearly uniform measurements, the variations being slight.

All cases were free from any constricting clothing at the time of the examination, and the rectum was emptied by cathartic or enema before the examination.

With the patient in the knee-breast posture, and the rectum, vagina, and bladder all dilated by atmospheric pressure, it was found that the true pelvis was always completely occupied by these three organs, and that the bladder and the uterus tended to rise upward and forward. In multiparæ the uterus was found to be displaced so far upward and forward that its fundus could be felt within a few centimeters of the umbilicus, Fig. 4.

The ballooning of the rectum and vagina before the bladder was allowed to fill with air was found to be of great importance to the ease of the examination of the ureteral orifices, in the fact that the dilated rectum and vagina press from behind upon the base of the bladder, thus bringing the trigonum and ureteral orifices forward and into easy view of the speculum. *Neglect of this point and failure to first allow the rectum and vagina to dilate is accountable in large measure for the difficulty found by so many gynecologists in catheterizing the ureters.*

The ureteral orifices were seen on, or were indicated by, a slight elevation of the mucous membrane, the "mons ureteris" of Kelly, but in some cases in young nulliparous women, the ureteral opening was indicated by a small round black point. Such a black point was never observed in older women who had borne children.

The bladder, as a whole, when dilated with air and observed during operation within the pelvic cavity—from abdominal section—was found to be ellipsoidal in form, flattened somewhat in its anteroposterior diameter and increased transversely. The transverse diameter was always the greatest measurement. Mathematical calculation of the cubic content of an ellipsoidal viscus of dimensions of the bladder corresponded closely with the actual air capacity obtained by expression.

The average length of the urethra in seventeen cases was 3.3 cm., the shortest urethra measuring 2.7 and the longest 4.2 cm.

It is hoped by the writers that the measurements and observations here recorded, though limited to so small a number as twenty-five cases, may prove of interest by affording a certain amount of carefully ascertained facts about the relative measurements and topography of the female bladder under air dilatation in the knee-breast posture.

[3] To Messrs. Brödel and Becker of the Johns Hopkins Hospital, we wish to express our indebtedness for the beautiful drawings from which Figs. 2, 3 and 4 have been made.

[4] This observation is also opposed to the statements of some text-books of anatomy, and is confirmed by Mr. Brödel.

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